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BRIEF REPORT

Resolving Ambiguous Behavioral Intentions by Means of Involuntary Prioritization of Gaze Processing

Matthew Hudson and Tjeerd Jellema
University of Hull

Anticipation of others' actions is of paramount importance in social interactions. Cues such as gaze direction and facial expressions can be informative, but can also produce ambiguity with respect to others' intentions. We investigated the combined effect of an actor's gaze and expression on judgments made by observers about the end-point of the actor's head rotation toward the observer. Expressions of approach gave rise to an unambiguous intention to move toward the observer, while expressions of avoidance gave rise to an ambiguous behavioral intention (as the expression and motion cues were in conflict). In the ambiguous condition, observers overestimated how far the actor's head had rotated when the actor's gaze was directed ahead of head rotation (compared to congruent or lagging behind). In the unambiguous condition the estimations were not influenced by the gaze manipulation. These results show that social cue integration does not follow simple additive rules, and suggests that the involuntary allocation of attention to another's gaze depends on the perceived ambiguity of the agent's behavioral intentions.

Keywords: action anticipation, representational momentum, emotional expression, approach avoidance, Fuzzy Logic Model of Perception

Cues such as gaze direction, facial expression and head rotation are potent sources of information in social interactions, and share an intricate relationship (cf. Adams & Kleck, 2003; Ganel, Goshen-Gottstein, & Goodale, 2005; Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007). The aim of this study was to investigate their joint contribution to perceptual judgments of others' actions, especially when the behavioral intent of the observed action is ambiguous. Judgments of other's actions are likely to be affected by anticipations formed by the observer on the basis of social cues present during the immediate perceptual history (cf. Jellema & Perrett, 2003).

Recently we reported a social cue-mediated anticipation of movement whereby the anticipation of the action varies according to the gaze direction of the actor (Hudson, Liu, & Jellema, 2009). Estimations of how far a head had rotated were greater when the head's gaze was directed in advance of head rotation than when lagging behind head rotation. This suggests that observers' expectancies of how the action would continue are affected by inferences about the goal or intention of the action based on the gaze direction cue. We concluded that representational momentum effects (cf. Freyd & Finke, 1984) of biological motion are mediated not only by inferences based on the inferred physical dynamics causing and constraining the motion, which typically apply to nonbiological motion (speed, friction, and gravity) (Hubbard, 2005), but also by inferences about the behavioral intentions underpinning the action. In other words, basic perceptual processing of others' actions is influenced by attributions of mental states and intentions to the other. This could be seen as a kind of *perceptual mentalizing* (cf. Teufel, Fletcher, & Davis, 2010), but reflecting the involuntary and implicit influence of top-down mental state attribution on social perception rather than explicit mental state attribution.

Normally, a palette of social cues is available to the observer, on the basis of which he or she attributes intentions and anticipates others' actions. In particular, the co-occurrence of facial expression and gaze direction constitutes an informative social stimulus. Basically two models have been put forth to explain how interactions between cues may influence the attribution of intentions. The shared signal hypothesis (SSH; Adams & Kleck, 2003; Hess, Adams, & Kleck, 2007; Sander et al., 2007) proposes that when different cues convey the same information, such as to approach or withdraw, attributions can be made with increased certainty, which facilitates the processing of either cue. When the cues convey conflicting information interference results, which impairs the processing of either cue. For example, angry faces are detected faster and are perceived with greater intensity when the expresser's gaze is directed toward the observer rather than away, while an averted gaze enhances the detection and perception of fearful faces (Adams & Kleck, 2005; Hess et al., 2007; Sander et al., 2007),

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Matthew Hudson and Tjeerd Jellema, Department of Psychology, University of Hull, Hull, United Kingdom.

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Correspondence concerning this article should be addressed to Matthew Hudson, Department of Psychology, University of Hull, Cottingham Road, Hull, East Yorkshire HU6 7RX, United Kingdom. E-mail: matthudson50@gmail.com

although it has been contested that this effect is stimulus specific (Bindemann, Burton, & Langton, 2008). Furthermore, the on-screen duration of an angry face is perceived as longer if the gaze is mutual rather than averted (Doi & Shinohara, 2009).

The second model is the Fuzzy Logic Model of Perception (FLMP; Massaro & Cohen, 1990, 1993). Fuzzy logic is a technique for drawing definite conclusions from complex systems that generate vague, ambiguous, or imprecise information, such as the human face. It is characterized by assumptions of continuous and independent features, which oppose the assumptions of holistic and categorical models, and by a multiplicative combination of feature values, rather than an additive one. Like the SSH, the FLMP proposes that processing of social cues is facilitated when they convey the same information. The two models differ, however, in the predictions made when the meaning of the social cues contradict each other, making the agent's intention ambiguous. Such cases pose an interesting challenge for models that try to explain social cue integration. Where the SSH predicts that opposing cues cancel each other, the FLMP predicts that processing will be prioritized to the most reliable cue. The FLMP model has been successfully applied to the integration of multiple cues in a variety of contexts, including the integration of facial features in judgments of emotional expression (Ellison & Massaro, 1997), and the integration of expression with cues of vocal affect (Massaro & Egan, 1996).

The social cue mediated anticipation of motion observed by Hudson et al. (2009) was obtained using faces displaying a neutral expression throughout the presentation. Due to the lack of motivational information conveyed by the neutral facial expression, gaze direction was the most informative cue regarding the goal/intention of the action and influenced the judgments of head rotation. The current study aimed to investigate social cue integration by explicitly introducing ambiguity in the above paradigm. This was achieved by combining a rotation toward the observer with an emotional expression conveying either a motivation to approach (joy, anger) or to avoid (fear, disgust). When the agent's facial expression signals approach, then expression and head rotation signal the same, and therefore unambiguous, motivation to move toward the observer. However, when the agent's expression signals avoidance, then the two cues suggest opposing behavioral intentions, rendering the agent's behavioral intention ambiguous. The SSH predicts that the effects of gaze manipulation on the estimations of the end-point of the action will be greatest in the unambiguous condition, because both cues enhance each other, while it should be relatively small in the ambiguous condition, as the behavioral intentions conveyed by the two cues conflict and therefore (partly) cancel each other. In contrast, the FLMP predicts that the effect of the gaze manipulation will be greatest in the ambiguous condition, due to the involuntary prioritization of gaze direction to resolve the uncertainty.

Method

Participants

Forty-two participants took part in the study; all were students at Hull University. After applying exclusion criteria (see below), 30 participants were included in the analysis (mean age = 24.8 years, *SD* = 8.1; 25 females). All had normal or corrected-to-normal vision, and provided written informed consent prior to the experiment.

Stimuli and Conditions

The stimuli consisted of computer-generated faces of a male and female actor created with Poser 6 (Curious Labs, Inc., Santa Cruz, CA, and e frontier, Inc., Scotts Valley, CA), and were presented on a 21 in. monitor (100 Hz refresh rate) using E-Prime software (Psychology Software Tools, Inc., Sharpsburg, PA). The face was shown to rotate 60° toward the participant, starting from a full profile view (90°, left or right) and ending at an angle 30° from full face view. Motion was induced by presenting 16 frames of 4° interpolations for 40 ms each (640 ms in total). The top of the shoulders were visible and remained fixed at a 45° angle from the observer in the direction the agent faced at the start (Figure 1A).

The gaze direction of the agent was manipulated by specifying either a deviation of 20° in advance of the direction the head was rotating (gaze-ahead condition), a 20° deviation lagging behind the head rotation (gaze-lagging condition), or no deviation (0°) from head orientation (gaze-congruent condition). The 20° angle difference between the gaze and head directions remained constant throughout the rotation.

The face expressed one of four emotional expressions at about maximal intensity: two approach expressions (anger and joy) and two avoidance expressions (fear and disgust) (Figure 1B, C). The subtended angle of the head's height was 6.9° for the female and 6.4° for the male stimulus. The subtended angle of its width varied from 5.1° to 4.1° as the stimulus rotated.

The test stimulus consisted of two static heads (both of the same identity as in the video-clip) presented side by side, each with neutral expression and congruent gaze (Figure 1A). One was oriented at an angle before (-) the final angle of the rotating stimulus (i.e., an orientation that was included in the observed rotation), the other was oriented after (+) the final angle (i.e., an orientation that would have resulted had the rotation continued). Participants were required to choose which test head was at an angle most similar to the final angle of the rotating head (which was always at 30°, left or right). The deviations of the test choices from the final angle varied along three levels. In each level one of the two choices deviated by 10° from the final angle, the other choice deviated by 10°, 20°, or 40°.

It was expected that an effect of the social cues on the similarity judgments would be most evident when the difference between each choice and the final angle was minimal and symmetrical (−10°/+10°). These were called the *symmetrical experimental* trials. Overestimation would be reflected in a bias to choosing the "after" choice, underestimation in a bias to choosing the "before" choice, while an unbiased estimation would be evident in an even proportion of the two response types.

In two additional levels, the difference of the remaining test choice was increased to 20°, such that either the "before" (−10°/+20°) or "after" (−20°/+10°) answer was correct. These were the *asymmetrical experimental* trials, and were included to see if the social cues could induce errors in the presence of a correct answer. Finally, in the remaining two levels, the deviation of one of the test choices from the final angle was increased to 40°. The correct answer of "before" (−10°/+40°) or "after" (−40°/+10°) was

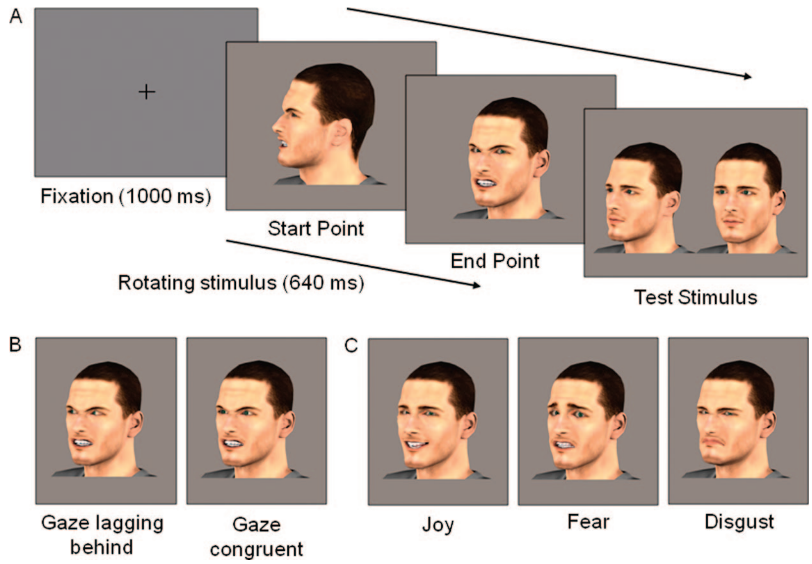

Figure 1. Stimuli. (A) Trial procedure. The male agent is shown rotating from the left, with an expression of anger and gaze directed "ahead," followed by a symmetrical Test stimulus ($-10°/+10°$). (B) The gaze-lagging and gaze-congruent conditions are shown at the final rotation angle for the anger expression. (C) Facial expressions of joy, fear and disgust are illustrated at the final rotation angle in the gaze-ahead condition.

deemed sufficiently obvious that these were used as catch trials to detect participants not paying proper attention to the task.

Procedure

Participants completed 192 trials (see Figure 1) in three blocks (10 min each). Each trial began with a fixation cross (1,000 ms) followed by the rotating head (640 ms), after which the test stimulus was presented. The latter remained on screen until a response was made. The choice between the left and right test heads was made by pressing the *J* and *L* key respectively (labeled accordingly). The gaze and motivation conditions (2×3 levels) contained 96 symmetrical experimental trials (16 repetitions), 48 asymmetric experimental trials (8 repetitions), and 48 catch trials (8 repetitions). The correct answer in the asymmetric experimental trials and catch trials was "before" in half the trials and "after" in the other half. The sex of the stimulus (male, female), direction of rotation (from the left or right) and position of the "before" and "after" test heads (left, right) were counterbalanced across trials. Written and verbal instructions were given, in which no reference was made to the gaze and expression manipulations. It was emphasized that accuracy was more important than speed, but that responses were to be made within 3 seconds.

Results

Twelve participants were excluded due to high error rates (>20%) in the catch trials. For the remaining 30 participants, 4.6% of trials were removed due to RTs being less than 250 ms, or

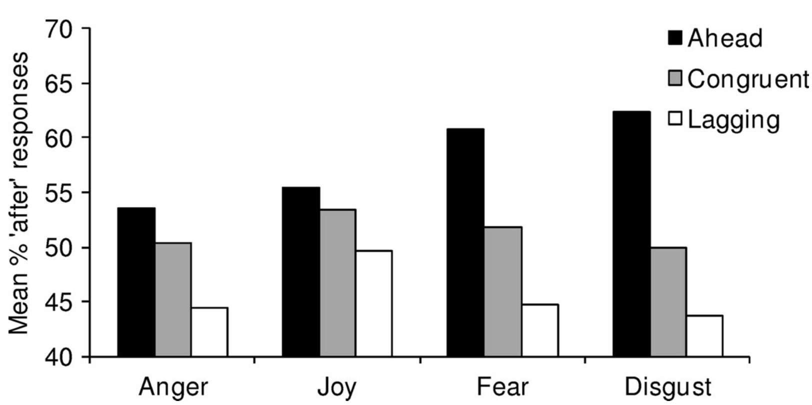

Figure 2. The effect of gaze direction on estimations of head rotation. The mean percentage of "after" responses elicited by each of the three gaze directions (ahead, congruent, lagging) are shown for the four expressions (Anger, Joy, Fear and Disgust) in the symmetrical trials.

greater than 2 SD of each participant's mean (mean RT = 1782.3 ms, SD = 516.2 ms).

Responses to the binary choice of either the "before" or "after" test head were coded as 0 (before) or 1 (after), providing a score for each participant of the mean percentage of "after" responses (overestimation). These percentage scores were entered in a 2×3 ANOVA with Motivation (Approach vs. Avoid) and Gaze direction (Ahead vs. Congruent vs. Lagging) as within-subjects factors. This analysis was conducted separately for the symmetrical and asymmetrical trials as the former are more sensitive to an effect of gaze direction due to the absence of a correct answer. As participant exclusion created ceiling performance in the catch trials, these trials were not analyzed further.

In the symmetrical trials, there was no main effect of Motivation, $F(1, 29) = .437$, $p = .514$, $\eta_p^2 = .015$, but there was a significant main effect of Gaze direction, $F(2, 58) = 10.7$, $p < .001$, $\eta_p^2 = .269$, with gaze ahead (M = 58.1%, SD = 20.2%) producing most "after" responses, followed by gaze-congruent (M = 51.4%, SD = 19.9%), followed by gaze-lagging (M = 45.7%, SD = 19.3%). Importantly for our hypothesis, a significant interaction between Motivation and Gaze direction was found, $F(2, 58) = 3.93$, $p = .025$, $\eta_p^2 = .119$.

Following this interaction, we investigated the presence of an effect of Gaze direction in the Approach and Avoidance conditions separately. As each of the motivation conditions comprised two different expressions, the factor of Expression was included to investigate if the effect of gaze was equivalent for each expression (anger and joy in the Approach condition, fear and disgust in the Avoidance condition).

In the Approach condition, there were no main effects of either Gaze direction, $F(2, 58) = 2.3$, $p = .11$, $\eta_p^2 = .073$, nor Expression, $F(1, 29) = 1.73$, $p = .199$, $\eta_p^2 = .056$, and no interaction, $F(2, 58) = .142$, $p = .868$, $\eta_p^2 = .005$. In the Avoidance condition, there was no main effect of Expression, $F(1, 29) = .025$, $p = .875$, $\eta_p^2 = .001$, but there was a main effect of Gaze direction, $F(2, 58) = 16.9$, $p = <.001$, $\eta_p^2 = .368$. Paired sample t tests between the three gaze direction conditions (pBon = .017) showed that the gaze-ahead condition elicited significantly more "after" responses than the gaze-congruent, $t(29) = 4.82$, $p < .001$, $d = .54$, and gaze-lagging, $t(29) = 5.06$, $p < .001$, $d = .87$, conditions. The latter two conditions did not differ from each other, $t(29) = 2.05$, $p = .05$, $d = .33$. There was no interaction between Gaze and Expression, $F(2, 58) = .162$, $p = .851$, $\eta_p^2 = .006$, with the effect of Gaze direction being significant for both Fear, $F(2, 58) = 7.36$, $p = .001$, $\eta_p^2 = .202$, and Disgust, $F(2, 58) = 9.37$, $p < .001$, $\eta_p^2 = .244$.

In the asymmetrical trials, there were no main effects of Motivation, $F(1, 29) = .993$, $p = .328$, $\eta_p^2 = .034$, and Gaze direction, $F(2, 58) = 1.5$, $p = .232$, $\eta_p^2 = .051$, nor an interaction between the two, $F(2, 58) = 1.24$, $p = .297$, $\eta_p^2 = .042$ (Figure 2).

Discussion

This study investigated whether two social cues conveyed by an actor, that is, facial expression and gaze direction, affected the observer's estimation of how far the actor's head had rotated. In particular, we examined the role of the agent's gaze direction when the agent's action was either unambiguous or ambiguous in terms of the underlying behavioral intention. A facial expression of approach (joy and anger) displayed by an approaching actor enabled the observer to reliably infer that the behavioral intention was to move forward (toward the object of interest). We found that in this unambiguous condition, the judgments of head rotation were not influenced by the gaze cue. In contrast, a facial expression of avoidance (fear and disgust) conflicted with the head rotation toward the observer, giving rise to ambiguity with respect to the behavioral intention. The gaze cue did influence the judgments in this ambiguous condition, that is, head rotation was overestimated when gaze was directed ahead of head rotation. This suggests that only in the ambiguous situation do participants scrutinise the eye region, which allowed the gaze cue to influence the decision making process. In other words, the processing of gaze direction was prioritized in an attempt to disambiguate the agent's intention. This process happened involuntarily and at a subconscious level as debriefing of participants indicated that most of them had not noticed the gaze manipulations. Thus, we argue that the perceived ambiguity of the agent's behavioral intentions induced an involuntary allocation of attention to the agent's gaze.

It should be noted that we made the basic assumption that when two social cues convey conflicting information with respect to the behavioral intention of the agent, the behavioral intention is perceived as ambiguous. Although there is no direct empirical evidence for this assumption, there is ample indirect evidence. For example, speeded responses made to label the facial expression of a stimulus face depend on whether the gaze direction of that face is congruent or incongruent with the behavioral intention conveyed by the facial expression. That is, RTs to recognize the frontal view of facial expressions of anger and joy (both signaling an intention to approach) were faster when the stimulus face displays direct gaze compared to averted gaze. Similarly, RTs to recognize facial expressions of sadness and fear (both signaling an intention to withdraw) were faster with averted gaze than with direct gaze (Adams & Kleck, 2003). It seems that the conflicting information causes interference in the observer's decision-making process, which is reflected in increased RTs. In another study, frontal facial expressions of anger and fear were shown to either increase or decrease in size, giving the impression of moving toward and away from the observer, respectively (Adams, Ambady, Macrae, & Kleck, 2006). Participants had to provide speeded responses to the direction of motion (toward or away). For the expression of anger, movements away took longer to detect than movements toward, which is again consistent with the notion that conflicting behavioral intentions cause interference (or response competition) resulting in longer response times. For the expression of fear, the movements away and toward did not affect the RTs, possibly reflecting a motivation to "freeze" rather than to retract in response to the threatening stimulus (see Adams et al., 2006 for a discussion). Support for the idea that gaze can be given precedence over facial expression and other social cues to resolve the uncertainty/ambiguity comes from different lines of enquiries. For instance, gaze can help identify the referent of another person's emotional expression (Hanna & Brennan, 2007; Repacholi, 1998), and can be used as a cue to someone's disposition when their facial expression is neutral (Adams & Kleck, 2005) or when the expression is rendered ambiguous via morphing procedures (Graham & LaBar, 2007). The use of gaze to disambiguate behavior is evident early in development. When the intentions underlying an observed action are unclear, 9-month-olds will attend more to the actor's gaze than when the intentions are easily discernable (Phillips, Baron-Cohen, & Rutter, 1992).

The current results do not reflect the simple additive processes of the SSH, but may be better understood within the FLMP, in which the perception of social cues is a nonholistic and nonadditive feature-based process. Some models of emotion recognition have indeed incorporated the fuzzy nature of emotions (Fiorentini & Viviani, 2009; Russell, 1997). Our results suggest that the FLMP may also be successfully applied to social cue integration. In the unambiguous case, the facial approach emotions combined with the rotation toward the observer exhibited a high degree of correspondence with the goal-prototype of approach, which was subsequently attributed to the agent. There was no need to prioritize gaze processing. However, in the ambiguous case, there was a correspondence with the goal-prototypes of both approach and avoidance, which meant the behavioral intention remained undecided. Consequently, processing of the gaze cue was prioritized to try and clarify the intention. Subsequent experiments will be needed to determine quantitatively the extent to which the results match the predictions made by the FLMP.

One could argue that in the case of anger, it may be beneficial to the observer to determine quickly whether the anger is directed at him/her or somewhere else, and therefore to monitor gaze direction. The results, however, are more in keeping with a role for gaze direction in anticipating others' actions when their behavioral intentions are ambiguous. Furthermore, a threat bias does not explain the biases in estimations of head rotation induced by the gaze manipulations reported by Hudson et al. (2009) for faces with a neutral expression. Those results can be better understood within the framework of the FLMP, as neutral expressions are inherently ambiguous with respect to behavioral intention (Adams & Kleck, 2005).

In principle, several alternative explanations could be proposed to account for the finding that gaze induced an effect for facial expressions of disgust and fear, but not for those of anger and joy. First, particular emotions may attract the observer's attention specifically to the eyes or mouth, that is, toward or away from the experimental manipulation. Recognition of fear expressions requires attention to the eye region (Adolphs et al., 2005; Smith, Cottrell, Gosselin, & Schyns, 2005), which may facilitate an effect of gaze compared to expressions of joy, for which attention is biased to the mouth region (Smith et al., 2005). However, determining anger expressions also relies on the eye region (Adolphs et al., 2005), for which no effect of gaze was found. Moreover, the expression of disgust does not preferentially attract attention to the eyes (Wong, Cronin-Golomb, & Neargarder, 2005), and is more recognizable from the mouth and nose region than the eye region (Calder, Young, Keane, & Dean, 2000; Smith et al., 2005), yet we found a highly significant effect for the gaze manipulation of disgust. Moreover, it seems unlikely that attention would be selectively drawn away from the eye region for joy, as gaze following has been found to be enhanced for joy (Hori et al., 2005; Striano & Stahl, 2005). Such findings suggest that differential allocation of attention to the eyes for different emotional expressions cannot account for the observed results. In future research, eye tracking should be used to examine this alternative hypothesis more closely.

Second, the distinctive widening of the eyes characteristic of fear expressions may have increased the conspicuousness, and therefore the effect, of the gaze manipulation (cf. Tipples, 2005), in contrast to happy expressions where the eyes are narrowed (Mehu, Little, & Dunbar, 2007). However, this does not account for the effect obtained for the disgust expression, in which even more squinting of the eyes occurs (see Figure 1C), yet the greatest gaze effect was obtained. Furthermore, inspection of the maximum on screen size of the eye showed only marginal variation between expressions (between 0.006° and 0.01° in height, and between 0.026° and 0.03° in width).

Third, we should consider the possibility that the effects found were related to enhanced gaze-following when gaze direction was averted (i.e., gaze-lagging and gaze-ahead), triggered by fear and disgust, but not by joy and anger. Although there are reports to the contrary, the consensus seems to be that typical individuals do not show enhanced gaze-following in response to expressions of fear (e.g., Hietanen & Leppanen, 2003). An enhanced gaze-following effect for fear only seems to become apparent when observers are high in trait anxiety (Fox, Mathews, Calder, & Yiend, 2007; Mathews, Fox, Yiend, & Calder, 2003), or when the task requires an affective evaluation of the target (Pecchinenda, Pes, Ferlazzo, & Zoccolotti, 2008). Given that our sample was drawn from the typical population (with no reason to believe that they possessed elevated levels of trait anxiety), and no affective evaluations of the target were required, we argue that enhanced gaze following for fear expression cannot explain the observed results. Again, future research could use eye tracking to further discount this alternative explanation.

In conclusion, successful navigation of the social world relies on anticipating other people's behavior. However, the integration of social cues on which such anticipations are based has received relatively scant attention. This study suggests that the information conveyed by gaze and expression is assimilated into the representation of the action itself (cf. Jellema, Baker, Wicker, & Perrett, 2000) and contributes to the observer's inferences as to how the action is most likely to continue. It further shows that an observer does not automatically allocate attention to an agent's gaze direction, but rather that the involuntary allocation of attention to gaze is flexible and depends on the perceived ambiguity of the agent's behavioral intentions. When more than one cue is available on which to base the decision, the relative contributions of each do not necessarily follow an additive rule. In particular, gaze processing will be prioritized when the other social cues are indecisive as to the immediate course or goal of the action, to try and resolve this ambiguity.

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